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ABSTRACT

This study reports on cultural and gender differences in the spatial abilities of children based on the Water Level Task. The Piagetian theory of age-related developmental differences in performance on the Water Level Task was explored with Chinese and Malay children living in Singapore. Results indicate that children in this study did not perform as well as those described in the Piagetian developmental stage. There was a significant difference in the performance of Chinese and Malay children with Chinese children performing better than Malay children. At all grade levels, boys had higher proportions of correct scores than girls; however, differences were not statistically significant. (KHR)

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Cultural and Gender Differences in Spatial Ability of Young Children

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Studies on Spatial Ability

Studies on cultural and sex differences in spatial abilities have been conducted from as early as 1946 when the WAIS (Wechsler Adult Intelligence Scale) was used. Most of these were carried out in USA and Europe but very few in Asia. In Singapore, research in gender differences related to spatial abilities is scarce and it was not till the 1980s that spatial ability studies involving mathematics achievement and gender differences in the elementary schools were documented.

In 1974, Maccoby and Jacklin published an extensive literature review that clearly established the existence of sex differences in spatial abilities favouring males. Hyde (1981) used meta-analysis to estimate the magnitude of the sex difference reported by Maccoby and Jacklin (1974) and found that sex accounted for only 5% of the variance in the spatial tasks they sampled. However, another meta-analysis done by Linn & Petersen (1985) based on effect size procedure, found that there are three distinct categories of spatial ability tests: spatial perception, mental rotation and spatial visualization. Sex differences were significant only in the first two categories. These meta-analyses suggest that spatial ability is not a unitary concept but is made up of a grouping of several different types of ability.

The inconsistent results of sex differences in spatial ability research can be due to the lack of a clear definition of what spatial abilities include. A large variety of tests has been used and several researchers have attempted to identify spatial ability factors but there has been no agreement on the categorization of spatial ability. In 1995, Voyer, Voyer and Bryden performed another meta-analysis covering 50 years of spatial ability research. They found significant gender differences in spatial abilities supporting males on some of the 12 tests that were used. The effect sizes in favor of males vary considerably from test to test, indicating that different measures of spatial ability assess somewhat different processes. This raises questions as to why gender differences do or do not occur.

Furthermore, most of the studies that have found gender differences in spatial ability were investigated in Western cultures. Boys have superior scores in spatial ability mainly from these western studies. Not enough is known whether gender differences in spatial skills also exist in non-Western cultures although a few studies have been documented. Mann, Sasanuma, Sakuma and Masaki (1990) found gender

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differences in a Mental Rotation Test in high school students in Tokyo, Japan. In 1993 Lee found males performing better than females on the Hidden Figures Test, Card Rotation Test and Paper Folding Test in Taiwan. However, in a study by Pontius (1997) twenty four male and twenty four female schoolchildren (ages 8 to 10) in Northwest Pakistan performed two spatial tasks without showing essential gender differences. Apparently, males in some Asian cultures will be superior in spatial ability depending on the spatial test used.

In a 1996 study from Norway by Vederhus & Krekling, it was reported that there were sex differences in 9 year old children on a battery of multiple choice tests representing all three spatial ability categories described by Linn and Petersen (1985) Data was collected from a total of 200 children from a random sample of elementary schools . The tasks included one test for each of the categories : Spatial Perception (Water Level Test) and Spatial Visualization (Surface Development task) and two tests of Mental Rotation (2D and 3D tasks). Their study showed that boys performed better than girls on all tests. This was significant for the Water Level task. On the other hand, females show superior performance on tasks that require verbal language abilities. In a related study in 1997 by Benjamin, sex differences in visual-spatial performance among Ghanaian and Norwegian adults were examined. This study found that both the patterns and the magnitudes of sex differences on tasks representing three different visualspatial ability categories were remarkably similar among Ghanaian and Norwegian adults and that the intercorrelation patterns between spatial tests were different in the two samples. This finding indicates that culture-related differences in spatial ability structure may still exist.

Given these findings, this study attempts to extend current research understanding about cultural and gender differences in spatial ability of children based on the Water Level Task.

Water Level Task

The Water-Level Task (WLT) was originally developed by Piaget and Inhelder (1956) to measure a child's ability to perceive space within an Euclidean reference system. In this task the child is required to correctly anticipate the water surface orientation in tilted bottles that are half filled. In the paper and pencil version of the WLT (Li et.al 1999) the child draws a line to represent the water level in several drawings of tilted containers. (Figure 1)

According to Piaget and Inhelder (1948/1956), success on the WLT reflects a person's spatial competence that is, the ability to use a Euclidean system of reference to organize spatial experience. On the basis of the findings from their experiments, Piaget and Inhelder expected children to master the WLT by approximately 9 years of age, when concrete operational thought has developed; for some, however, Piaget and Inhelder said that mastery might not come until age 12. According to Li et.al (1999) a number of studies indicate that many American students fail the WLT. Neither boys nor girls performed accurately on the WLT before adolescence and that only boys showed significant age-related improvement from 5th to 12th grade.

Within age groups, gender differences have also been indicated. Thomas and Turner (1991) found that across age groups, male individuals outperformed female individuals, and within each gender group, there were high performers and low performers. At the high school level, girls had lower scores than boys on the WLT and at the college level, women had lower scores than men. The age at which gender differences begin to appear is also questionable since some studies reported that gender differences appear at all age levels, whereas as early as 1976 Geiringer and Hyde found that gender differences appeared in the 12th grade but not in the 5th grade.

It has been noted that Asian students have performed better than American students on spatial tasks like the WLT (Li & Shallcross, 1992; Li etal., 1996). About 91% of the Chinese men and 76% of the Chinese women were successful on the WLT, compared with 56% of the American men and 26% of the American women. In a later study (Li etal 1999) Chinese college students in China outperformed Chinese American college students. In addition, among the Chinese American men, those who could write Chinese performed better than those who could not write Chinese.

The Singapore Study

In the present study, we explored the applicability of the Piagetian theory of age-related developmental differences in performance on the WLT with Chinese and Malay children living in Singapore. Singapore is a multi cultural society, predominantly Chinese in population followed by the Malays, Indians and Eurasians. The participants were 100 children (aged 8 to 12) from an elementary school in a typical housing estate.

The standard paper and pencil WLT was used. It has a total of eight drawings of bottles tilted at different degrees. The children were told to imagine that each bottle was being held over a tabletop, represented by the line under each bottle. They were to imagine that the bottle was sealed and that it was half filled with water. They were asked to draw a line representing what they thought the surface of the water would look like in each bottle. The child's score was the proportion of water lines, which were within 5 degrees of the horizontal. For this task, the split-half reliability estimates have been established to be .91 for males and .92 for females.

Results

Performance on WLT by Age/Grade (Table 1)

Most of the children at primary 2 (typical age 8 years) had not mastered the water-level task. For the eight water-level bottles depicted, the average proportion correct was .42 (ie the mean score per child was .42 out of a possible 1.00) for primary 2 and .63 for primary 3 (see Table 1). Only 30% of the primary 2 children and 23.8% of the primary 3 (9 years) got all eight correct. For primary 4 (10 years) 34.5% answered all eight WLT items correctly. The mean proportion correct was .69. This was the same for primary 5 (11 years) and primary 6 (12 years). Data seem to show that there are two stages of performance on the WLT: all primary 2 and below 8 years and primary 3 , 4,5 and 6 and all above 8 years.

Proportion correct on the WLT by Race, Gender and Grade (Table 2 and Table 3)

More boys above age 8 have higher proportions of scores correct compared with all the girls .This however is not statistically significant. The Chinese children however do better than all the Malay children and this is statistically significant, $F(2,99) = 4.589$, $p=.012$. The interaction between race and gender was not significant.

WLT scores for 8 Bottles (Table 4)

Three types of scores are given : Zero for wrong response; Half for responses within the 5 degree horizontal and Full for correct 'horizontal' response. Bottle 2, 3, 5 and 6 have more incorrect responses than the other bottles.

Discussion

The present results indicate that the Piagetian developmental stage of 9 year olds , as reflected in the WLT, does not correspond to the scores of the 9 year old Singapore children tested. Less than half of the 9 year old children had developed the spatial and cognitive abilities required for the WLT. There were more than half who could not solve the WLT at ages 10,11 and 12. This finding is similar to a 1976 study by Geiringer and Hyde who reported that neither boys nor girls perform accurately on the WLT before adolescence. Overall, children in this study did not perform as well as those described in Piaget's reports.

At all grade levels, boys perform better on the WLT than girls. There was no statistically significant interaction between grade level and gender. This finding is quite consistent with the meta-analytic studies by Linn and Petersen (1985) and Voyer et al (1995) that male individuals consistently perform better than female individuals on the WLT at all ages. This study provides cross cultural evidence of gender difference in WLT performance from age 8 to 12.

It has been pointed out by Linn and Petersen (1985) that males did better than females on spatial tasks due to less effective strategies used by the latter. It was also noted that females tend to take more time, reflect more caution and tend to double check their responses. Females tend to view spatial tasks as more difficult than do males.

The better overall test performance of the Chinese children compared to the Malay children may indicate differential experience and socialization from these two racial groups .The poorer performance of the Malay children is probably based on their response to the demand characteristics of the WLT test situation rather than inherent racial or ethnic differences in spatial perception ability. The data in the present study is too insufficient to warrant any definitive statement about the different response patterns from these two racial groups.

On the whole the WLT is difficult for children because it requires a number of cognitive and perceptual competencies. It is a multi dimensional problem requiring

both knowledge of physical principles and spatial perceptual abilities. Kalichman (1989) reduced the WLT to four subabilities: visual-perceptual skills, mental imagery and rotation skills, use of spatial coordinate systems and recall of relevant information. Graphic and disembedding skills are also required. This probably explain why the WLT seem to be more difficult for children from one culture than another and also for children from within a same culture.

In interpreting the present study, caution is advised. There is much diversity between the Chinese and the Malay children. In addition to environmental and social economic factors, there maybe other differences such as home values, practice of ethnic culture, experience with spatial relations and language differences. Also, it is important to keep in mind that current behaviorial and neuroscience research have been examining the processes that give rise to sex differences in the brain from different cultures. Evidence suggest that the effects of sex hormones on brain organisation occur so early in life that from the start, the environment is acting on differently wired brains in girls and boys. Such differences make it almost impossible to evaluate the effects of experience independent of physiological characteristics.

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Table 1. Scores for the Water-Level Task (WLT) by grade level

Grade	Age (Years)	N	WLT score	% all correct
Pr 2	8	11	.42	30
Pr 3	9	21	.63	23.8
Pr 4	10	29	.69	34.5
Pr 5	11	31	.69	29
Pr 6	12	8	.69	25

Table 2. Proportions correct on the WLT, by race, gender and grade

Age	8		9		10		11		12	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Race										
Chinese	.73	.53	.61	.68	.73	.85	.75	.77	0	.75
Malay	.25	.25	.50	.67	.60	.57	.63	.75	.13	.75
Others	0	0	0	0	.75	.75	.19	.50	0	.88

Table 3. Means of correct scores by sex and race

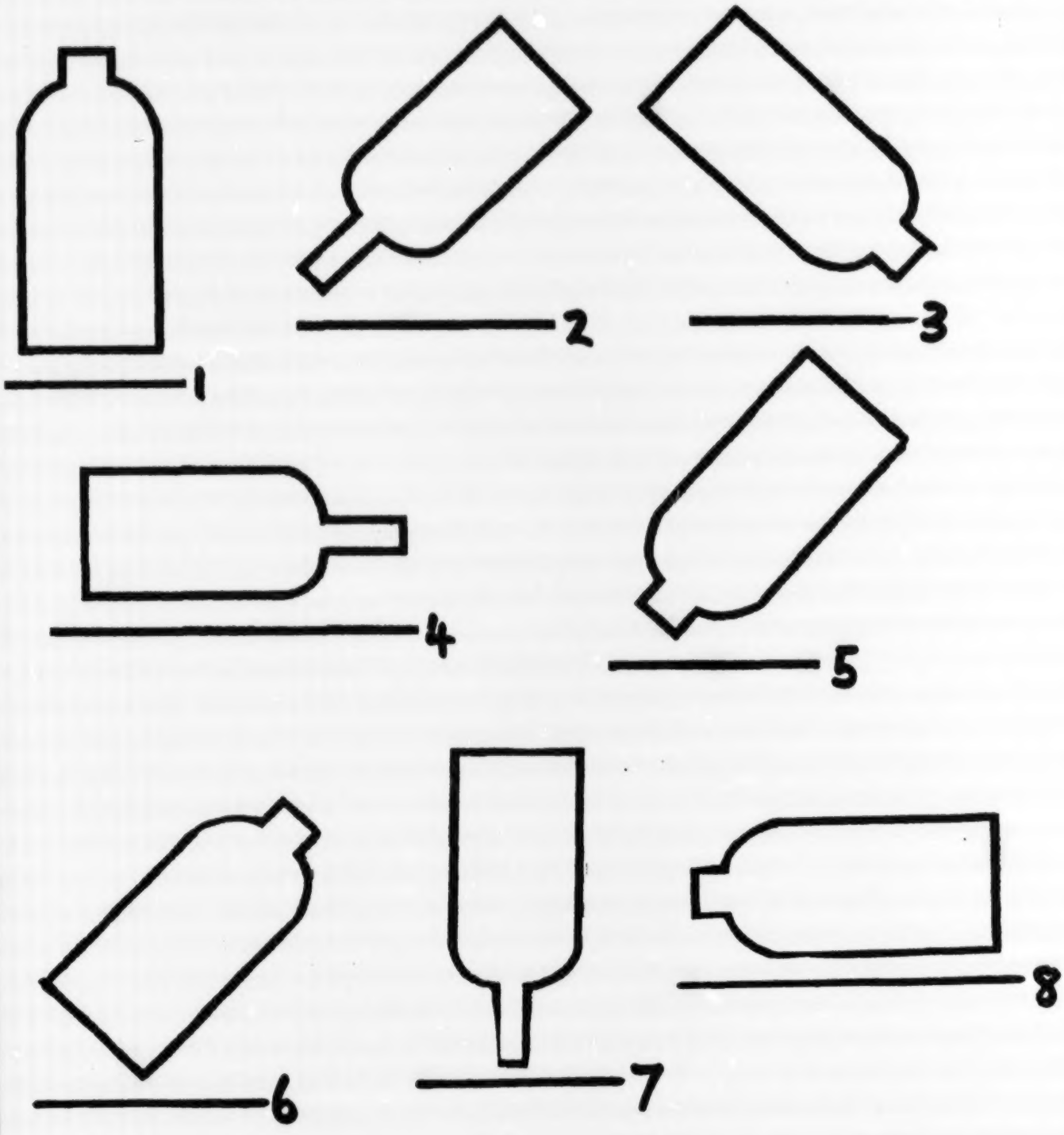
	Female			Male			Total		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Chinese	26	5.62	2.56	31	6.06	2.03	57	5.86	2.28
Malay	15	4.27	1.79	23	4.91	1.88	38	4.66	1.85
Others	3	3.00	2.65	2	5.50	2.12	5	4.00	2.55
Total	44	4.98	2.43	56	5.57	2.02	100	5.31	2.21

Table 4. Water-Level Task (WLT) scores for 8 bottles (B1-B8)

Score	B1	B2	B3	B4	B5	B6	B7	B8
Zero	0	49	51	19	54	48	5	16
Half	0	9	7	0	6	4	1	0
One	100	42	42	81	40	48	94	84

Figure 1

Imagine that each of the bottles you see on the paper is being held over a table top, represented by the line under each bottle.
Imagine that the tops of the bottles are sealed and that they are about half-filled with water.
Draw a line representing what you think the surface of the water would look like in each bottle.



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